

Article

Comparison of the Effects of Inhalational Anesthesia with Sevoflurane and Total Intravenous Anesthesia in Open Heart Surgery

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Abstract

Background: The primary objective of this study was to compare sevoflurane inhalation anesthesia with total intravenous anesthesia (TIVA) in terms of its effectiveness in maintaining adequate depth of anesthesia during all open heart surgery procedures, including cardiopulmonary bypass. The study's secondary objective was to compare sevoflurane inhalation anesthesia with TIVA regarding the impact on the time of tracheal extubation and the incidence of postoperative acute kidney injury during open heart surgeries. **Methods:** A total of 58 patients undergoing open heart surgery were included, with 30 receiving sevoflurane inhalation anesthesia and 28 receiving TIVA. Demographic characteristics, intraoperative parameters, and postoperative outcomes were recorded and analyzed. Statistical analysis revealed no significant differences in Bispectral Index (BIS) monitor values, mean arterial pressure, body temperature, or other intraoperative parameters between the two groups. Notably, the time to tracheal extubation was significantly shorter in the Sevoflurane group compared to the TIVA group, although both groups exhibited similar rates of postoperative acute kidney injury (AKI). **Results:** None of the patients had complaints of intraoperative awareness. The mean arterial pressure, body temperature, and bispectral index values during and before cardiopulmonary bypass were similar between the groups. Postoperative variables such as intensive care unit stay duration, incidence of acute kidney injury, and immediate and 24-hour post-extubation visual analog scale values were similar between the groups. The tracheal extubation time was found to be statistically shorter in the sevoflurane group. **Conclusion:** We believe that sevoflurane inhalation anesthesia can achieve adequate depth of anesthesia during the intraoperative period in open heart surgery without increasing the rate of postoperative complications.

Keywords

anesthesia; inhalation anesthesia; sevoflurane; intravenous anesthesia; cardiac surgery

Introduction

While technological advancements in open heart surgery have progressed, the optimal anesthesia management for patients undergoing this procedure remains to be precisely defined. In anesthesia management for open heart surgeries, intravascular anesthetic agents are used alone or in combination with volatile anesthetic agents [1,2]. Total intravenous anesthesia (TIVA) and volatile anesthesia are two primary anesthesia management approaches adopted for patients undergoing open heart surgery. The comparison of these anesthesia methods primarily focuses on their cardioprotective effectiveness. Only a limited number of studies have compared Volatile anesthesia and TIVA based on factors such as the maintenance of anesthesia depth, time of tracheal extubation, and the occurrence of postoperative acute kidney injury (AKI). Different studies have reported diverse outcomes addressing these matters [3–5].

A meta-analysis indicated that applying volatile anesthesia or TIVA in open heart surgery does not cause a significant effect on the time of tracheal extubation [5]. In contrast, a prospective randomized study comparing desflurane inhalation anesthesia with TIVA in patients undergoing aortic valve replacement (AVR) surgery reported that the time to tracheal extubation was shorter in patients receiving desflurane inhalation anesthesia compared to the TIVA group [3].

The primary objective of this study is to compare sevoflurane inhalation anesthesia with TIVA in terms of its effectiveness in maintaining adequate depth of anesthesia during all open heart surgery procedures, including cardiopulmonary bypass. The study's secondary objective is to compare sevoflurane inhalation anesthesia with TIVA re-

garding the impact on the time of tracheal extubation and the incidence of postoperative AKI during open heart surgeries.

Materials and Methods

Following the ethics committee approval (Derince Training and Research Hospital Ethics Committee: 2021-3), we retrospectively analyzed the files of patients who underwent open heart surgery at our hospital's operating rooms between 1 September 2019, and 1 April 2020. The study included 72 patients aged between 18 and 75 who underwent open heart surgery, with intraoperative anesthesia management and postoperative intensive care monitoring conducted by the same team and for whom Bispectral Index (BIS) monitoring was applied. Of all patients whose files were screened, eight patients with a left ventricular ejection fraction (LVEF) below 40%, four patients with moderate to severe restrictive lung disease, and two patients requiring emergency surgery were excluded from the study. The remaining patients were divided into two groups based on the methods employed for anesthesia maintenance. Thirty patients for whom anesthesia maintenance was achieved with sevoflurane at every stage of the surgery, including the cardiopulmonary bypass (CPB) period, were classified as the Sevoflurane group. Twenty-eight patients for whom anesthesia was maintained with total intravenous anesthesia (TIVA) throughout the procedure were classified as the TIVA group (Fig. 1).

Demographic characteristics, laboratory results, existing chronic illnesses, and medications received were recorded for each patient during the screening of their files. Similarly, the information on the anesthesia monitoring form, including electrocardiography (ECG), mean arterial pressure (MAP), urine output, and BIS values were documented for all patients. Additionally, the CPB duration, cross-clamp duration, inotropic agents used, amounts of blood products administered, and the number of defibrillations applied after cross-clamp removal were recorded for all patients.

Information including time of extubation, drainage amounts, quantities of blood products used, and kidney function values on the third day were recorded for all patients from the intensive care monitoring forms. Patients with a 1.5-fold increase in creatinine values on the postoperative third day compared to preoperative creatinine values were classified as positive for AKI based on the Risk, Injury, Failure, Loss, End-Stage Kidney Disease (RIFLE) criteria [6].

Anesthesia Method

All patients included in the study received 1 mg/kg lidocaine (Jetmonal 2%, Adeka drug, Istanbul, Turkey) be-

fore anesthesia induction to prevent the hemodynamic response secondary to direct laryngoscopy. No other premedication was administered to the patients.

The following data were provided for all patients; Invasive and non-invasive blood pressure (NIBP), heart rate by ECG, peripheral Pulse oximetry (SpO₂) and Bispectral Index monitoring were performed. A BIS Quatro Sensor (Aspect Medical Systems, Newton, MA, USA) was applied to the forehead of each patient for depth of anesthesia measurement. Invasive blood pressure monitoring was initiated with radial artery cannulation before anesthesia induction. After induction of anesthesia, the patient's core temperature was monitored with a thermocouple temperature probe inserted into the esophagus.

After anesthesia induction; In the Sevoflurane group, adequate depth of anesthesia was achieved by adjusting the maintenance of anesthesia sevoflurane (Sevorane, Abbvie Turkey, Istanbul, Turkey) concentration to reach the target BIS value of 40. Patients in this group were also given analgesic doses of fentanyl (2 mcg/kg) (Fentanyl-Pf 100 mcg/2 mL, Polifarma, Kirklareli, Turkey) every 60 minutes. In the TIVA group, infusion was provided with a manually adjusted infusion pump after the induction rate. The depth of anesthesia was maintained using propofol (2–6 mg/kg/hour) (Propofol-Pf 1% 200 mg/20 mL, Polifarma, Kirklareli, Turkey) and remifentanyl (0.08–0.2 mcg/kg/minute) (Ultiva 2 mg, Vld Drug, Istanbul, Turkey) infusions to achieve a BIS value 40.

All patients' pupil diameters were checked at regular intervals after anesthesia induction. In cases of a relative increase in pupil diameter, even if there was no increase in BIS value, the concentration of sevoflurane in the Sevoflurane group and the infusion rates of propofol and remifentanyl in the TIVA group were increased.

For postoperative analgesia, all patients were administered intravenous tramadol (100 mg) (Contramal 100 mg/2 mL, Abdi Ibrahim, Istanbul, Turkey) and paracetamol (1000 mg) (Parol 10 mg/mL, Atabay, Kocaeli, Turkey) in repeated doses. The postoperative pain levels of patients were assessed using the Visual Analog Scale (VAS) immediately after extubation and at 24 hours. Postoperative pain treatment in the study patients was provided with tramadol and paracetamol treatment according to the VAS score. Fluid therapy was routinely planned with 100 mL/hr balanced crystalloids, and individual decisions were made regarding discharge procedures.

CPB Method

All surgical procedures were conducted by the same surgical team per a standardized approach. A Terumo roller pump (Terumo Advanced Perfusion System 1, Terumo BCT Tıbbi Cihazlar, Istanbul, Turkey) and membrane oxygenators (Dideco Compactflo Evo oxygenator, Sorin Group Italia, Mirandola, Italy) were utilized. Mild to moderate

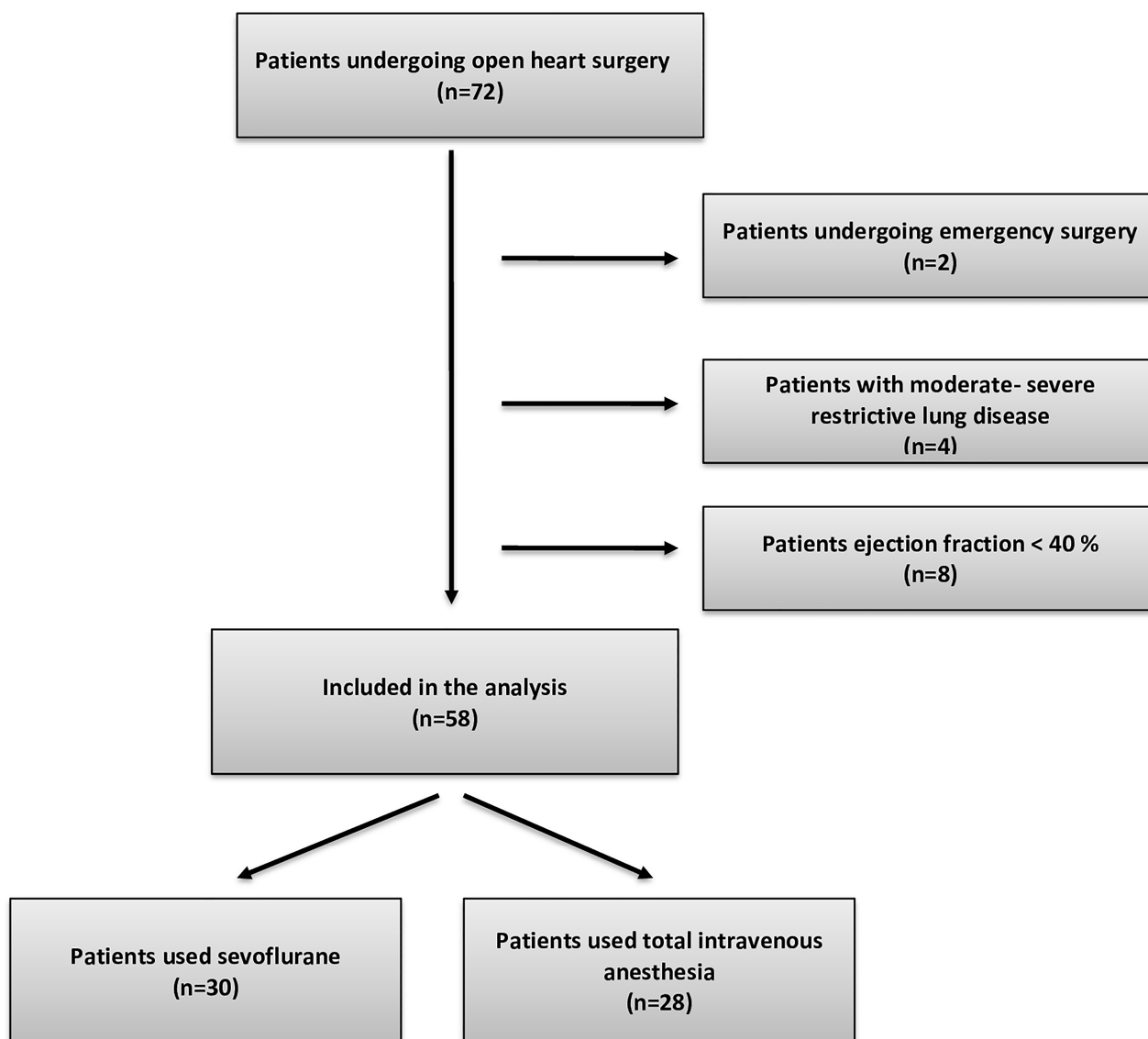


Fig. 1. Flow chart.

systemic hypothermia, maintained at a temperature range of 28–32 °C, and a continuous (non-pulsatile) pump flow of 2.2–2.4 L/m² were employed throughout the operations.

After the placement of the aortic cross-clamp, 1000 mL of blood cardioplegia (20 meq potassium chloride + 10 cc sodium bicarbonate + 10 cc 15% magnesium sulfate) (Potassium Chloride 7, 5%10 ML, Menarini, Istanbul, Turkey) (Sodyum Bikarbonat 8, 4%, Farmalaz, Istanbul, Turkey) was administered through the antegrade cardioplegia cannula. In isolated coronary artery bypass graft surgery (CABG) patients, 500 mL blood cardioplegia (10 meq potassium chloride + 5 mL sodium bicarbonate + 5 mL 15% magnesium sulfate) was repeated after each distal anastomosis and every 20 minutes in valve patients. To prevent ventricular fibrillation observed after the aortic cross-clamp removal, 5 mL of 2% lidocaine (Jetmonal 2% , Adeka drug, Istanbul, Turkey) and 10 mL of 15% magne-

sium sulfate Magnezyum Sulfat %15, Biofarma, Istanbul, Turkey) were administered prophylactically before the aortic cross-clamp removal.

During CPB, the mean perfusion pressure (MPP) was maintained in the 60 to 90 mmHg range. A bolus dose of noradrenaline was administered in case of a fall below 60 mmHg. When MPP exceeded 90 mmHg, despite no increase in BIS value, the infusion rate of propofol and remifentanyl in the TIVA group and the sevoflurane concentration in the Sevoflurane group were increased. The acid-base balance was maintained at physiological levels (pH 7.35 to 7.45), where sodium bicarbonate was used if needed.

Before CPB, heparin (300–400 units/kilogram) (Heparin Sodyum, Vem Ilac, Istanbul, Turkey) was administered to maintain the activated clotting time (ACT) value between 480 and 600. During CPB, ACT was checked at regular

intervals. When the ACT value fell below 480, additional heparin was administered through the heart-lung pump. After CPB, protamine was used as a heparin antagonist to reduce the ACT value to 130.

Statistical Analysis

Data obtained from the study were analyzed using IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA). To compare the numerical data, an independent samples t-test was used for the nominal spread, and the Mann-Whitney U test was used for the non-nominal spread. A chi-squared test was used to analyze the discrete variables. The results were within the 95% confidence interval, and a p -value of <0.05 was considered significant.

We determined the study's sample size based on a pilot study that included 10 patients [7]. It was determined that 17 patients in each group would be adequate for the sample size with an 80% power ($\alpha = 0.05$, $\beta = 0.2$, and a confidence interval of 95%). As a result, the study was completed with 30 patients in the Sevoflurane group and 28 in the TIVA group. The Minitab program (Minitab, Inova Software, Ankara, Turkey) was used with the Power and Sample Size test, incorporating average and standard deviation parameters for determining the sample size.

Results

In this study, data from a total of 58 patients were analyzed, with 30 in Group 1 and 28 in Group 2. The average age of all patients participating in our study was 62.2, with a minimum of 33 and a maximum of 76. The most common comorbidities in the patients participating in the study were smoking with 48.2%, diabetes mellitus (DM) with 46.5%, and hypertension (HT) with 44.8%. Statistical analysis demonstrated a significant similarity between the groups concerning age, gender, LVEF, height, weight, and body mass index. Additionally, a statistically significant similarity was observed between the groups regarding the incidence of DM and HT, as well as smoking and alcohol habits ($p > 0.05$; Table 1).

In the study, the groups' mean arterial pressure, body temperature, and BIS values were compared before and during CPB. A statistically significant similarity was found between the groups in terms of mean arterial pressure values before and during CPB. Furthermore, there was a statistically significant similarity between the groups in terms of body temperatures before and during CPB. The groups also had a statistically significant similarity regarding their BIS values before and during CPB (Table 2).

The study also compared the groups in terms of intraoperative variables. The distribution of surgical procedure types among the groups was statistically similar. There was a statistical similarity between the groups regarding total anesthesia duration, CPB duration, cross-

clamp time, amount of blood products used, and the number of defibrillations after cross-clamp. Additionally, the amount of ephedrine or norepinephrine administered as bolus, the need for inotropic support for pump weaning, and the amount of urine during the pump were observed to be statistically similar between the groups ($p > 0.05$; Table 3).

The study compared the groups in terms of postoperative variables. None of the patients had complaints of intraoperative awareness. The time to extubation in sevoflurane group was found to be statistically shorter. However, the length of stay in the intensive care unit was below 3 days in both groups and was statistically similar. VAS values immediately after extubation and at 24 hours, drainage amount, and postoperative blood product use were found to be statistically significantly similar between the groups ($p > 0.05$; Table 4).

The renal functions of the patients were evaluated preoperatively and on the third postoperative day. Creatinine values measured preoperatively and on the postoperative third-day, creatinine were statistically similar between the groups. AKI was observed in 3 patients in the Sevoflurane group, whereas no patients in the TIVA group experienced AKI. However, the rate of AKI between the groups was statistically similar ($p > 0.05$; Table 5). There was no need for continuous renal replacement therapy in the three patients who developed AKI. The pre-discharge medical approach provided adequate recovery in these patients.

Discussion

In our study comparing sevoflurane inhalation anesthesia with TIVA during open heart surgery, we found similar BIS, body temperature, and MAP values at every stage of the operation in both groups (Table 2). The anesthesia duration, CPB duration, cross-clamp duration, need for inotropic support after pump weaning, bolus noradrenaline use, pump urine output, amount of blood products used intraoperatively, and the number of defibrillations applied after cross-clamp removal were found to be similar between the two groups (Table 3). There was no difference between the two groups in terms of the length of stay in the intensive care unit, the amount of blood product used postoperatively, drainage amount, and VAS values at extubation and 24 hours. However, the time to tracheal extubation was significantly shorter in the Sevoflurane group compared to the TIVA group (Table 4). Additionally, creatinine values and the incidence rate of AKI were similar between the two groups (Table 5).

Several studies in the literature compare volatile anesthesia with TIVA in open-heart surgery [2,3]. These studies primarily focus on cardioprotective efficacy [3,5]. Only a limited number of studies have specifically compared volatile anesthesia with TIVA in terms of maintaining anesthesia depth, tracheal extubation time, and postoperative AKI [8]. When the literature is examined and compared

Table 1. Comparison of demographic data of groups.

		Group Sevoflurane (n = 30)	Group TIVA (n = 28)	p
Age (y)		63.67 ± 9.43	60.75 ± 8.19	0.096
Gender	Female	6 (20.0%)	6 (21.4%)	0.893
	Male	24 (80.0%)	22 (78.6%)	
Left ventricular EF (%)		54.67 ± 7.65	53.93 ± 8.54	0.787
Height (cm)		167.30 ± 8.58	171.21 ± 8.20	0.082
Weight (kg)		76.27 ± 14.47	83.07 ± 12.70	0.063
BMI		27.13 ± 4.29	28.42 ± 4.46	0.267
DM (+)		15 (50.0%)	12 (42.9%)	0.586
HT (+)		13 (43.3%)	13 (46.4%)	0.813
Smoking (+)		13 (43.3%)	15 (53.6%)	0.436
Alcohol (+)		4 (13.3%)	3 (10.7%)	0.760

TIVA, Total intravenous anesthesia; EF, Ejection fraction; BMI, Body mass index; DM, Diabetes mellitus; HT, Hypertension. +: presence of this parameter.

Table 2. Main clinical variables before and during CPB (Average of all time points before and during CPB).

	Group Sevoflurane (n = 30)	Group TIVA (n = 28)	p
Before CPB mean arterial pressure (mmHg)	67.10 ± 7.69	64.97 ± 8.35	0.317
During CPB mean arterial pressure (mmHg)	59.89 ± 7.25	58.23 ± 5.28	0.328
Before CPB temperature (°C)	35.63 ± 0.51	35.71 ± 0.46	0.447
During CPB temperature (°C)	31.55 ± 1.08	32.16 ± 0.51	0.575
Before CPB BIS	37.43 ± 4.97	39.21 ± 3.95	0.137
During CPB BIS	35.76 ± 4.86	36.33 ± 4.72	0.730

CPB, Cardio pulmonary bypass; TIVA, Total intravenous anesthesia; BIS, Bispectral index.

with our study, it is a new finding that the use of sevoflurane during heart-lung pump significantly shortens the postoperative extubation time compared to TIVA.

BIS monitoring is commonly used for tracking the depth of anesthesia in open-heart surgery. The BIS (BISTM, Medtronic, Inc., Minneapolis, MN, USA) is a widely used processed electroencephalogram monitor for estimating the hypnotic level during anesthesia [9,10]. The target is to maintain the BIS value in the range of 40 to 60 for adequate depth of anesthesia [11,12].

There are various opinions regarding the use of BIS in open heart surgery. It is reported in a review that clinical conditions such as hypothermia, acid-base imbalances, electrolyte abnormalities, hypovolemia, and low cardiac output during open heart surgery may lead to changes in BIS values independent of the depth of anesthesia [13,14]. Nevertheless, using BIS during open heart surgery is strongly recommended [13]. In a study by Bartholmes *et al.* [15] involving 57 patients undergoing open heart surgery, the BIS value was targeted to be kept below 50, and the average BIS value was found to be 43. In that study, none of the patients experienced intraoperative awareness. Based on the results reported by Bartholmes *et al.* [15], we thought that BIS monitoring could be used during open heart surgery; however, due to specific conditions inherent to open heart surgery, such as hypothermia, acid-base imbalances, electrolyte abnormalities, hypovolemia, and low cardiac output,

the target BIS value should be reduced. For this reason, in our study, we set the target BIS value at 40.

In our study, which primarily aimed to evaluate the effectiveness of sevoflurane inhalation anesthesia and TIVA in achieving adequate depth of anesthesia during open heart surgery, the BIS values of patients in the Sevoflurane group and TIVA group were statistically similar; both below 40, both before and during the operation of the pump. In our study, there was no report of intraoperative awareness from any of the patients.

We interpreted these results to suggest that inhalation anesthesia with sevoflurane in open heart surgery has similar effectiveness in achieving adequate depth of anesthesia as TIVA and that targeting an average BIS value of 40 can prevent intraoperative awareness.

We believe that the ideal anesthesia management for open heart surgery is expected to result in a shorter time to tracheal extubation and a brief stay in the intensive care unit without causing an increase in potential complications in the postoperative period. Early tracheal extubation is also the most crucial step in fast-track cardiac care, which is widely implemented due to its aim to shorten the duration of intensive care and hospital stay, besides its numerous advantages [16–20].

There is no consensus on the impact of volatile anesthetic agents versus TIVA on tracheal extubation time in open heart surgery [3–5,21].

Table 3. Comparison of intraoperative variables of the groups.

		Group Sevoflurane (n = 30)	Group TIVA (n = 28)	<i>p</i>
Operation type	CABG	28 (93.3%)	22 (78.6%)	0.407
	AVR	1 (3.3%)	2 (7.1%)	
	MVR	0 (0.0%)	1 (3.6%)	
	CABG + AVR	1 (3.3%)	1 (3.6%)	
	CABG + MVR	0 (0.0%)	2 (7.1%)	
Anesthesia duration (m)		311.63 ± 20.23	321.32 ± 18.65	0.064
CPB time (m)		101.17 ± 30.28	106.46 ± 38.75	0.563
Cross clamp time (m)		66.40 ± 24.60	63.21 ± 28.55	0.539
Use of bolus noradrenaline		12.43 ± 6.85	14.43 ± 5.33	0.150
Pump output inotropic support		12 (40.0%)	10 (35.7%)	0.737
Amount of urine during CPB (mL)		718.33 ± 349.00	728.57 ± 395.21	0.956
Amount of blood product use (units)		0.60 ± 1.04	0.54 ± 0.88	0.992
Number of defibrillations		0.10 ± 0.31	0.18 ± 0.48	0.591

TIVA, Total intravenous anesthesia; CABG, Coronary artery bypass grafting; AVR, Aortic valve replacement; MVR, mitral valve replacement; CPB, Cardio pulmonary bypass; m, minute.

Table 4. Comparison of postoperative variables of the groups.

	Group Sevoflurane (n = 30)	Group TIVA (n = 28)	p
Time to extubation (h)	4.69 ± 1.48	5.76 ± 2.02	0.029
Amount of drainage (mL)	605.33 ± 305.23	547.86 ± 189.78	0.731
Postoperative blood product Usage amount (units)	0.70 ± 1.34	0.71 ± 1.12	0.522
Stay in intensive care (d)	2.87 ± 1.04	2.93 ± 0.54	0.483
After extubation VAS	2.46 ± 1.40	2.39 ± 1.44	0.845
24th hour VAS	3.43 ± 1.67	3.28 ± 1.82	0.759

TIVA, Total intravenous anesthesia; VAS, Visual analog scale.

Two meta-analyses comparing volatile anesthetic agents with TIVA in open heart surgery have indicated no relationship between the choice of anesthesia management and time to postoperative tracheal extubation [5,21]. In contrast, a prospective randomized study making a comparison between desflurane inhalation anesthesia and TIVA reported that the time to tracheal extubation was shorter in patients receiving desflurane inhalation anesthesia compared to the TIVA group. However, in that study, the time to extubation was over 8 hours in both groups [3]. Yildirim *et al.* [8] investigated the effect of sevoflurane use during CPB on postoperative cardiac performance and presented the duration of mechanical ventilation as an outcome. However, unlike our study, this study underlined that the use of sevoflurane did not provide a significant change in the duration of mechanical ventilation [8].

In our study, whose secondary aim was to investigate the impact of sevoflurane inhalation anesthesia versus TIVA on the time of tracheal extubation in open heart surgery, the time to tracheal extubation was found to be statistically significantly shorter in patients in the Sevoflurane group. However, the time to extubation was below 8 hours in both groups [3]. We interpreted these results to suggest that sevoflurane inhalation anesthesia, similar to desflurane, may reduce tracheal extubation time compared to TIVA. We attribute the shortened tracheal extubation times in our

study with sevoflurane compared to the desflurane study to the fact that all extubation procedures were performed by the same team following the same criteria. Similar to our study, the literature emphasizes that tracheal extubation time can be shortened with a specified extubation protocol [22,23].

Acute kidney injury is one of the major complications that affect mortality and morbidity after open heart surgery. There are several contributing factors to the development of AKI after open heart surgery [24,25]. However, the most crucial point to be considered for protecting patients from developing AKI is to ensure continuous adequate renal perfusion at every stage of the operation. Maintaining continuous renal perfusion is achieved with stable hemodynamics. The incidence rate of acute renal injury after acute heart surgery ranges from 1% to 30% [24]. There are two separate studies conducted on AKI following open heart surgery in the period before the initiation of sevoflurane use during CPB in our clinic. In these studies, the incidence rates of AKI after open heart surgery in our clinic were reported to be 7% and 8.2%, respectively [24,25]. LVEF, CPB duration, aortic cross-clamp duration, and the amount of blood product used are all contributing factors that play a role in the development of AKI following open heart surgery [24–26].

Table 5. Comparison of kidney functions of the groups on the 3rd postoperative day.

		Group Sevoflurane (n = 30)	Group TIVA (n = 28)	<i>p</i>
AKI	–	27 (90.0%)	28 (100.0%)	0.323
	+	3 (10.0%)	0 (0.0%)	
Preoperative creatinine (mg/dL)		0.94 ± 0.25	0.99 ± 0.21	0.398
The 3rd postoperative day creatine (mg/dL)		0.98 ± 0.45	0.88 ± 0.20	0.676

TIVA, Total intravenous anesthesia; AKI, Acute kidney injury. – and +: Absence and presence of AKI.

In our study, there was no statistically significant difference between sevoflurane inhalation anesthesia and TIVA regarding the incidence of AKI. AKI was observed in 3 patients (10%) in the Sevoflurane group. However, no patient in the TIVA group experienced AKI. We interpreted this result as indicating that inhalation anesthesia with sevoflurane in open heart surgery cannot be considered a risk factor for increasing the incidence of postoperative AKI. We believe this result may be attributed to sevoflurane having similar hemodynamic effects to TIVA.

Our study and conducting similar studies in cardiovascular surgery have some limitations that must be acknowledged. The most important limitations of our study are that it was conducted retrospectively and in a single center, in a limited number of patients. Due to the nature of retrospective studies, there may be concerns about the reliability of the data. However, we believe that this situation was not found in our study. Because all the data in our study are perioperative follow-up data that are not open to interpretation and are standard in all cardiovascular surgery anesthesia follow-up forms, nursing follow-up forms and perfusionist follow-up forms. However, we could not use neurocognitive tests in our study, which are difficult to evaluate retrospectively and are not included in standard follow-up forms. Although comparison of neurocognitive functions was not the aim of our study, this is another limitation of our study. The first limitation is that BIS monitoring was performed only during the intraoperative period and not continued until extubation in the intensive care unit. However, we believe that the standardization of extubation criteria and the performance of extubation by the same team may mitigate the negative impact of this limitation on the results. Another limitation of the study is the lack of monitoring of patients' opioid requirements due to the absence of the necessary equipment for tracking the depth of anesthesia. Despite this limitation, we believe that appropriate doses of opioids were administered to patients in both groups. Because none of our patients experienced opioid-induced hyperalgesia, which is associated with excessive opioid use, and the measured VAS scores were low in both groups [27]. We believe that the administration of repeated doses of lidocaine and magnesium sulfate as antiarrhythmics and membrane stabilizers during open heart surgery may have contributed to the low VAS scores.

Conclusion

Inhalation anesthesia with sevoflurane during open heart surgery shows similarities with TIVA in terms of BIS values, the incidence rate of AKI, and postoperative VAS scores. Nevertheless, sevoflurane inhalation anesthesia provides shorter tracheal extubation time compared to TIVA. Considering these positive outcomes, we believe that sevoflurane inhalation anesthesia can achieve adequate depth of anesthesia during the intraoperative period in open heart surgery without increasing the rate of postoperative complications.

Availability of Data and Materials

Study data is open to sharing with appropriate request and written permission of the institution.

Author Contributions

Designed the research study; MY, VKY, AS, AY and KTS. Data collecting; EOY, AG and HS. Data analysis; MY, AS, AY and KTS. Writing and final checks of the article; MY, VKY, EOY, AY, AG, HS, AS and KTS. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The ethics committee approval; Derince Training and Research Hospital Ethics Committee: 2021-3. All patients signed the informed consent form.

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Conflict of Interest

The authors declare no conflict of interest.

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